The Last Word

In Omni 'The Last Word' appears at the end. With us if comes at the beginning! Perhaps that is symptomatic of the OUGS. The reason for the rather despairing editorial title for this issue is that, as far as I can tell, this is the last thing I write for the Journal. As you will see when reading through it, I've written most of this issue. I've had one Branch Report from Wessex, one from my own branch and one written by a trip leader who is not an OUGS member. The rest of the world seems to have been hit by World War III. I'm not writing any more - if you want a Journal get writing! Otherwise I'm afraid the Journal must be considered moribund.

Before I start crying in my soup I better tell you about this issue. The bulk of it, once again, is taken up with a report on this year's very successful Conference. I apologise in advance to those who think I've missed the most important point of the weekend, or have unfairly represented their favorite speaker, and to those who think that the 500 odd slides should have been included in the report. If this comes out after the Evolution exam I also apologise for not getting it to the OU in time for them to print and dispatch it to you (production is out of my control - honestly!). I expect, however, that those who attended will find the report a useful aide memoir and that those who didn't make it to Oxford will get something of the flavour of the weekend.

It looks from field trip attendance that the recession is beginning to bite. Day trips attendance has been noticeably disappointing, though weekend trips are still oversubscribed. Next year more effort will be made in putting on weekends in some of the remoter areas, such as Cornwall, Wales and Scotland, to give those of you further from the active conurbations a better choice, but this will mean more travelling for others. The success of this scheme will depend on the support we get from those in whose areas we run the weekends. If we arrange a trip in your area please join in, even if you prefer not to pay for the accommodation. You will always be welcome to tag along during the day, and if you want to join in the social side in the evenings this can normally be arranged at a reasonable cost.

Before I forget, in case there aren't any writers among you (hint, hint, hint), the tenth Conference will be at Reading (the venue for our first Conference) from the 9th to 11th July 1982 and will be entitled 'A Decade of Geological Change'. It promises to give the speakers a wide subject range and to produce some interesting insights into how geology has changed in the lifetime of the OUGS. If you don't book early you may never get to know what affect the OUGS has had on the geological world!

Martin Bryan

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The 1981 Conference

The 1981 Conference was started with a bang on Friday evening by Dr. Jake Hancock of Kings College, who took as the subject for his after-dinner lecture the Late Cretaceaous Extinctions. He first explained that the extinctions of genera such as ammonites and belemnites in the Late Cretaceous was not the simple one-off catastrophic event some geologists try to portray it as.

Looking at the boundary between the Cretaceous Maastrichtian formation and the Tertiary deposits above it on a section of the Vrvenhaven canal in the Maastrichtian type area in south-east Holland we see a distinct erosion horizon between two sets of shallow-sea carbonates, with the lower part of the strata being so deeply eroded in places that it has proved difficult to be sure which horizon recovered microfossils came from.

The type locality for the Danian, the lowest of the Palaeocene deposits, in Denmark shows, in contrast, a sharp change in lithology between it and the underlying Maastrichtian sediments, which suggests that some major break occurred in this locality, perhaps involving some erosion. We aren't as yet sure what really happened at this time.

Care must be taken when looking at graphs, etc, that seem to show complete extinctions of some Cretaceous faunas on the same day that other species sprang into existence, with no changes occurring before or after this event. If you look at the family rather than the species level you will find that the 'extinction', particularly of the ammonites, is more like a steady drop in the numbers of families within the species over the 30 million years of the Cretaceous. A recent change in the taxonomic definitions of the ammonites has, however, changed this picture slightly, suggesting that a big decrease occurred somewhere in the Santonian, with the remaining families dying out just before the end of the Maastrichtian. This time of decrease could change again when the taxonoma of the post-Santonian ammonites are reviewed to the same level that has already taken place with the earlier ammonites.

There was also a parallel decrease in the geographical areas inhabited by the ammonites during this period. This constriction is noticeable throughout the world, with especially noticeable decreases being recorded in Japan, Australia, Antarctica, Nigeria and even Madagascar, which otherwise has the richest ammonite community of all.

The myth that the last of the Late Cretaceous ammonites were the ones that started to uncoil was then laid to rest by Dr. Hancock. The main abundance of the uncoiled ammonites occurred between the Turonian and Santonian in the middle of the Cretaceous, and it is now possible to show that many of the regularly coiled ammonites are descended from uncoiled or bizarrely coiled species.

Another problem with ammonites is that very few late ammonites are found in the type localities used for naming the divisions within the Cretaceous. The Kumrama Limestone, which contains most of the known European late ammonites, has not been equated with any of the type areas yet. Also some geologists think that many of the fossils found in the Maastrichtian are juveniles, rather than dwarf species.

Belemnites, on the other hand, had a worldwide distribution by the Middle Cretaceous, but at the start of the Upper Cretaceous, during the Samomanian, many families died out over large areas, so that by the Campanian the main areas for belemnites was what is now Eurpoe. The belemnites, however, just survived the Maastrichtian, as we know from some Eocene species which have been discovered.

Dr. Hancock inserted a word of warning here because, if you glance at the record of a species known as *Inoceremide*, they also appear to have almost died out by the end of the Campanian, with some later Tertiary fossils also being recorded from around the Mediterranean. If, however, you look carefully at the records you find that

find that most of the supposedly Tertiary specimens come from deposits, originally thought to be wholly Tertiary in origin, which later investigation has shown to have been deposited as one unit from the Late Cretaceous to the Tertiary. The remaining species are found in a faulted area near Bilbao in Northern Spain in what has now been shown to be an uplifted block of Cretaceous sediment in the otherwise Tertiary sediments of the area. Unfortunatley the original definitions of these fossils as Tertiary in origin has not been corrected to take account of these later findings!

The Rudists were also very common in the Maastrichtian, particularly in the Carribbean, but died out suddenly at the end of this stage, and the foraminifera were greatly depleted with, perhaps, only one genus surviving into the Tertiary.

All this evidence points to a gradual decrease in the abundance of fossils in the Cretaceous record, followed by a mass extinction at the end of the period, but this evidence must be tempered by the fact that not all species were affected, and also by the knowledge that some of the data this evidence is based on may be wrong, or may have to be re-evaluated later. It must also be remembered that the gradual rise in sea level during the Cretaceous was terminated by a return to the old levels at the end of the Maastrichtian, and that most of the Cretaceous fossils have been found in areas that were above sea level both before and after the Cretaceous.

Q. Could the changes in sea area have been responsible for the decrease in species diversification in the Cretaceous?
A. I don't think so. I can't see ammonites needing fixed feeding territories like those needed by carnivores, and I would expect them to be able to survive in quite small areas. Some families were fairly wide ranging, indicating that they were able to move about quite easily, so migration with changing sea level would be relatively simple I would have thought.

Q. Is there any evidence that increasing polar icecaps or vulcanicity may have led to a fall in sea level.
A. I know of no large icecaps at this time, but there was an increase in vulcanicity in the vicinity of Ireland and Sweden in the Late Cretaceous, with further activity throughout Europe in the early Tertiary. Whether the same factors could be used to explain extinctions elsewhere I'm not so sure.

Saturday morning started with a talk by Dr. Colin Scrutton from the University of Newcastle-upon-Tyne entitled 'Periodicity of the Earth's Rotation - Evidence from Fossils'. Astronomy and geophysics may appear to have little to do with palaeontology, but the much-acclaimed offspring of the cross-fertilisation between the two fields has proved of great interest, even though it now appears to be less healthy than once thought. Organisms generally are affected by the natural rhythms of the environment in which they live. This is as true of humans, who respond to both light and dark and to lunar influences, as of the other animals. The principal cycles involved are the solar daily cycle, the tidal cycle of fortnightly neap and spring tides, the monthly lunar cycle and the annual cycle of the seasons.

As well as affecting the general life of the organism these cycles also affect the construction of their skeletons. In the case of organisms that have a continuously additive mode of growth the skeleton at any time preserves a complete history of the growth of the organism, and this reflects the various cycles. Tree rings are one example. Another is in cockles, the periodicity of whose growth was noted by Leonardo Da Vinci. It is, however, a relatively recent observation that if you can find evidence of more than one cycle in a skeleton you can work out a relationship between the rhythms. This has provided researchers with a method of investigating the relative motions of the Earth, Moon and Sun in the geological past.

Fossil groups which have provided data on these relationships include the corals, bivalve molluscs, stromatolites, brachipods and cephalopod molluscs. Because of the impossibility of reviewing all these groups in one short lecture Dr. Scrutton concentrated on the bivalves, which are probably the best understood as more work has been done on living representatives. Firstly, however, Dr.

Scrutton briefly reviewed growth periodicities in the other groups.

Solitary corals have regular annular swellings of the external skeleton that correspond to internal density changes within the tissue, these possibly being due to annual changes in seawater temperature or light levels. Between successive annual rings are finer bands, which are probably linked to a lunar monthly cycle as they normally occur 13 times between the annual rings. These may reflect the breeding cycles in the corals. There is also evidence for finer daily growth-ridges, which seem to be solar in nature rather than reflecting the diurnal nature of the tides. These could be linked to the photosynthetic properties of algal symbionts in the living corals studied.

Stromatolites also display clear internal banding controlled by the action of algae on the surface of the mat. Daily, tidal, monthly and annual increments have been recognised in this banding, but most of this work has been done on Precambrian fossils rather than living structures. Work on present day stromatolites has shown how sensitive these growth increments are to the amount of sediment introduced into the environment. Another problem is that present day stromatolites are grazed by other animals and are, therefore, restricted to marginal environments. This would not have been the case in the Precambrian before the evolution of the metazoans, so extrapolation from the Recent may not be valid in the interpretaion of the ancient stromatolites.

Only one paper has published data on brachiopods, but it does not contain any illustrations or discussion on the nature of the growth increments. Dr. Scrutton expects that with more work they could possibly provided reliable and verifiable data.

Cephalopods seem to offer a source of data, but at the moment we cannot be certain of the growth period of the septa separating the internal chambers. It is possible that finer ridges on external parts of the shell may have a daily periodicity, but there seems to be some confusion with detailed ornamentation in the data published so far for this group. The comparison of septal spacing and ridge width is indirect because the two structural elements are not formed in the same part of the conch at the same time.

The bivalves, in contrast, provide good correlation detail. Cross-sections of shells clearly indicate the winter breaks during which growth decreases, breaks associated with spawning and, under the microscope, fine daily increments consisting of thick-thin doublets. Checks on living intertidal bivalves (cockles) have shown good correlation between variations in the thickness of the daily increments and the seasonal and fortnightly lunar cycles. The form of the daily variation can be shown to be linked to the lunar-controlled daily variations in tide, with calcification occurring only during immersion of the shell at high tide. Shell closure at low tide stops calcification, and the increasing pH inside the shell during this period results in the dissolution of previously deposited material and the formation of an organic-rich band.

It is important, however, to distinguish between bivalves growing in low latitudes and those growing in high latitudes, because annual growth stoppages in the higher latitude bivalves may result in missing increments. In addition, as the animals get older growth decreases. Generally bivalves seem to provide a very faithful record of environmental conditions, particularly of the states of the tide. It is even possible to detect individual openings and closings of the shell within the tidal cycle.

When interpreting the fossil record it must be borne in mind that the semi-diurnal tidal cycle recorded in the growth of bivalves around the British coast today is not universal. The character and timing of the tides varies in different oceanic configurations. With mixed semi-diurnal tides a switch-over effect occurs as the former low tide becomes the new high tide, which can result in the number of days recorded between two monthly or yearly cycles seeming to indicate a solar rather than a lunar link for the increments. The effect of the position of the living shell within the intertidal zone must also be considered. The higher up the beach the longer and more often the shell is closed, interrupting growth. Shells at the bottom of the intertidal zone may only be exposed at low spring

tides, whereas at the top of the zone the shells may only be covered, and hence open, during alternate tides. Some tropical bivalves, however, have associated symbiotic algae, which appear to give a true solar daily record due to growth being promoted by the photosynthesising algae.

When all this data is correlated, although the currently available figures are very crude, it is possible to use the fossil record to check the rate at which the Earth is slowing down as a result of lunar tidal friction and to determine how the Moon is moving in relation to the Earth. The data so far recorded suggests that there were formerly more days in the year and in the lunar month, and it corresponds suprisingly well with the predictions made as the result of historical astronomical observations. Future work should allow us considerably refine the accuracy of these figures.

Q. How far do you think the formation of supercontinents such as Pangaea may have affected the Earth's periodicity?
A. It is likely that there was some effect as there was less continental shelf to provide tidal drag at this stage. There is a suggestion in the fossil data of a change in the rate of slowdown in the Earth's rotation during this period, but the data is too crude for confidence in such a detailed interpretation.

Q. Do we know if there has been any change in the length of the Earth's orbit that may have affected the length of the year?
A. The basic assumption always made in these calculations is that the period of the Earth's rotation about the Sun is constant: otherwise there is no basis on which to do the calculations. Providing the gravitational constant (G) is constant the period will not change, and there is as yet no evidence for any change in G with time.

Our next speaker was Dr. Hugh Jenkyns from Oxford University, who took Marine Transgressions as his subject. He started by showing the various ways that sea level is thought to have been altered in the past. One of the most obvious ways to affect the sea level is to melt ice or freeze water in large quantities. In terms of the recent history of the Earth this type of change has been increasing in importance since the Oligocene, and it was also important in the Permian, Carboniferous and Early Palaeozoic.

Another commonly cited mechanism is changes in the volumes of ocean ridges, which are also affected by the spreading rates at each ridge. Ridges obey the law of age-depth constancy, which postulates that all bits of the seafloor of the same age have the same depth, and that this depth increases with age. This theory is often used to explain the chalk-producing Late Cretaceous transgressions.

Other theories postulate increased oceanic sedimentation or the innundation of previously evaporated basins that are situated below sea level, such as the basin that formed the Mediterranean.

Dr. Jenkyns then went on to explain how he came to be involved in a leg of the Glomar Challanger drilling programme between Hawaii and Tahiti, and to explain how the drilling was carried out. The leg was designed to test the hot-spot theory by checking if there was an age progression on the volcanic rocks formed along the Tuamotu Archipelago/Line Islands chain similar to that found along the similarly shaped Hawaiian Ridge/Emperor Seamounts chain. The sequence found in hole 315, the first of the successful holes, progressed from ooze to chalk, followed by cherty chalk and beds containing volcanogenic grains associated with shallow-water reef-asscoiated foraminifera, before finally coming to a sequence of claystones above the basement basalt. Turbidites were distinguishable in the volcanogenic sediments. In the next hole (316) one of the Cretaceous turbidite sequences was over 6ft in depth.

From evidence obtained in these two holes and the previously drilled hole 165 it was postulated, on rather dubious data, that there was no age progression along this chain, with all areas ceasing volcanic activity some 80 million years ago. However, basaltic age analysis was also used to postulate, by interpreting the data in a different way, an age progression from 72 to 100Ma. An analysis of reef debris dredged up along the chain, however, reconfirmed the 80Ma date for the whole chain!

Moving on to the Manikiki Plateau, two more holes were drilled, the second on the elbow of another chain. These showed that this chain is not of the same age as the Hawaiian Ridge or the Tuamotu/Line Islands chain.

Later Dr. Jenkyns was invited to go on a second leg between Guam and Marjuro Atoll (near Bikini Atoll). The first hole on this leg (462) was to be drilled through what was then thought to be the Jurassic crust of the Pacific. As no unequivocal Jurassic deposits had previously been retrieved from the Pacific, the prospects for this leg seemed very good. The early samples from the hole showed nicely bedded turbidites, followed by breccias and then coloured claystones containing native copper of the type that overlaid the basalts in the Line Islands. Eventually a mid-Cretaceous basalt was encountered, in an area where the geophysical data suggested that Jurassic deposits should be found. A second re-entry hole was then drilled alongside the initial pilot hole to get further cores through the basalt. After a time speckled sediment was encountered, indicating that intercalated sediment had been metamophosed at some point, and had therefore been intruded after deposition by post-Jurassic basalts.

Looking at the overall results of the drilling and the geophysical evidence, it was noticed that the Nauru Basin area was a little shallower than would have been predicted from the age-depth constancy law. By looking at other areas where volcanic piles have been pushed through a plate by hot spots it was seen that the depth of the plate crust appeared to be reset as part of the intrusion process to around 4.5km, irrespective of its original age of formation, before subsiding again at the rate described by the age-depth law. This process seems to have also occurred in the Nauru Basin, where an uplift after original deposition of some 1.6km is indicated. This occurred in the mid-Cretaceous and caused islands to appear on which a reef fauna developed, which subsequently formed the source of the mid-Cretaceous deposits found in the obtained cores.

Looking at the results from both legs there seems to have been quite a lot of Cretaceous intra-plate volcanicity, and these findings are further reinforced by results obtained elsewhere in the Pacific. The fauna in the associated sediments of this period also show a sudden change from deep to shallow-water types, again suggesting an uplift. Evidence from drill holes on Bikini and Eniwetok Atolls has shown that these islands have subsided 1.6km since the Eocene. Linked with the 110Ma date determined for the original sill complex found in hole 462, the evidence indicates that the original basalt was uplifted in the Cretaceous by some 1.5 to 2km and then, possibly after some erosion, subsided again to its present depth.

We know that the Cretaceous was a time of large-scale marine transgressions. The geophysical evidence for the Pacific now indicates anomalously shallow depths over a large area. If the whole Nauru Basin and associated areas were raised by 2km a 35m rise in world sea level would have occurred, which is not enough on its own to explained the whole of the Cretaceous rise.

Henry Menard of the US Geological Survey had previously postulated the existence of just such an updomed area, which he named the Darwin Rise, from the levels of sea guyots (before plate tectonics became fashionable). This previously rejected theory is now looking as if it may be correct.

The area that made up the Pacific during the Cretaceous can be seen to be made up of more than one plate, three of which have now largely been subducted. The associated plate material was subducted before the Eocene. The crust of the nearby Caribbean is also seen to be abnormally thick, being primarily formed of material intruded as a Late Cretaceous sill. This material may have been part of the Farallon Plate, one of the three Pacific plates since largely subducted. This plate may have provided the material forming the ophiolite complexes in the San Francisco area which are locally associated with limestones of shallow-water origin above highly vesicular basalt. South American ophiolites from the same plate contain Jurassic shallow-water foraminifera followed by Cretaceous to Tertiary planktonic foraminifera of deep-water origin.

Holes 315 and 316 of the Hawaii/Tahiti leg and hole 462 in the Nauru Basin also yeilded pseudorbitoids previously only known in the Caribbean/Central America area and two 'odd' occurrences in Papua and India. This shallow-water reef-associated fauna suggests that a band of reefs probably extended from the Caribbean to India during the Late Cretaceous, again supporting the Darwin Rise theory. Areas of the Indian and Atlantic Oceans also seem to show anonymously shallow areas that were formed around the same time, and these shallow areas would probably have resulted in a 70 to 100m rise in the sea level during the Cretaceous.

It is possible that the previously postulated increase in the rate of seafloor spreading occurred at the same time as this seafloor updoming, this in turn suggesting that the Earth was giving off a phenomenal amount of heat in a non-steady state process during this period. All this evidence is now coming together to provide a plausible explanation for the cause of the Cretaceous marine transgressions.

Q. It was pointed out earlier that there is no evidence for polar icecaps during the Cretaceous. Is it possible that this is because there were no landmasses at the poles during this period?
A. By Late Cretaceous times there was probably a landmass at one of the poles. There is, contrary to popular belief, evidence of some possible glacially-controlled periodicity in the sea level changes of the Mesozoic. There was perhaps a small icecap during this period.

Q. Is it possible that the heat generated during the updoming warmed the oceans enough to prevent freezing that might otherwise have occurred?
A. I don't know the answer to that. I suspect not.

The OU's own Simon Conway Morris took as his subject Early Metazoan Evolution. He told us that the earliest Precambrian fossils found include stromatolites, similar to those found today at places like Shark's Bay, which were formed by blue-green algae. These suggest that by Late Precambrian times conditions were similar to today's as far as temperature, oxygen levels and salinity was concerned.

Until near the end of the Precambrian there were no multicellular animals. Then the metazoans appeared on the scene, first as soft bodied animals and then increasingly with hard parts that could become fossilised.

One of the interesting areas for Precambrian Ediacaran soft bodied fossils is the Flinders Ranges in Australia. The anatomy of many of the organisms found there, which include such animals as sea pens, is comparatively well known, although there is further potential for detailed work. In Newfoundland some earlier examples have been found on the Avalon Peninsula. Here volcanic ash has smothered the soft bodied animals living on the seafloor so rapidly that impressions of their bodies have been preserved in life positions. Unfortunately the rocks here are so lithified that extraction is difficult. It is also difficult to determine the affinities of many of the simple fossils preserved in this sequence. Only one fossil, *Charnia*, has been identified at other locations, which include the type location in the Charnwood Forest.

Until animals started to develop hard parts around the start of the Cambrian metazoan fossils could normally be preserved only as soft bodied impressions. It is perhaps surprising that these seem more common in the Precambrian than later, but probably this is because scavengers and predators were rare and the corpses of the soft bodied animals were subject to less disturbance.

The first hard parts discovered occur in the form of rather nondescript worm tubes known as *Claudina*, which is found in limestones in South West Africa. These limestones were interbedded with sandstones containing impressions of Ediacaran soft bodied animals. Not until some 20-30 million years later do the next species with hard parts occur. These have been identified in Siberia, China and the Mackenzie Mountains of Canada. Later, certain other microfossils also developed hard parts, often formed from phosphatic material.

The trilobites didn't appear until later in the Lower Cambrian, when the fossil record makes it

seem that they became the main type of animal almost overnight. Apart from trace fossils, such as trails produced by trilobites, these animals with hard parts seem to make up the complete fossil record in most localities, and most representations of Cambrian life consist almost completely of fossils like these, with perhaps the odd polychaete worm to account for the burrows found in the sediments.

There is, however, one exceptional deposit, the 550 million year old Burgess Shale of British Columbia, that shows how small a part was actually played by animals with hard parts. More than 70 000 soft bodied organisms found by the bed's discoverer, Charles Walcott, form the basis of the collection now available for study in the Smithsonian Institution, and these have been augmented by thousands more specimens collected by the Canadian Geological Service in 1966/7. The Burgess Shale was deposited at the base of a rather problemetical 1000ft high Cambrian reef (whose origin has yet to be satisfactorily explained). They appear to have slumped from their depositional point at the base of the reef into an anaerobic zone, so causing the sudden death of the mainly benthic fauna.

When trying to determine the relative proportions of soft and hard bodied animals it is important to take into account the hard remains of previously dead animals, only taking account of those hard bodied animals that are either obviously in life positions or which still show evidence of having had soft parts. The assemblage found when this is done includes arthropods, sponges, brachiopods. worms, hemichordates and chordates. The trilobites become a minute proportion of the original living assemblage.

In the Burgess Shale most of the fossils have been flattened and have had their carbon replaced by silicates. This latter effect has allowed quite a lot of detail to be preserved, including some evidence of the food consumed by certain of the fossils. There is evidence that a priapulid preferred to eat its prey of hyolithid shells head first - a number of hyolithids being found lined up in the same direction within the stomach.

Sponges, sometimes attached to worm tubes, can also be found in their entirety within the shales, rather than in the normal form of loose spicules found elsewhere in Cambrian rocks. Five genera of polychaetes have also been identified, only one of which may have living relatives.

It is also possible to identify the normal Cambrian hard bodied fauna such as trilobites, but in this instance the soft parts have also been preserved, providing much evidence of the overall structure of the original animals. One common arthropod in the Burgess Shale is the *Marrella*, over 15 000 specimens of which have been identified. This was probably a deposit feeder which had external spines, antennae and feathery-like appendages for sweeping up detritus.

Some of the fossils contain protective spikes, etc - indicating a defensive capability even at this early stage of evolution. These were probably first developed by the grazing animals. Most of the specimens in the Burgess Shales can be attributed to recognisable phyla whose development can be mapped for many millenia. There are also, however, a few species that cannot be categorised in this way, including *Hallucigenia*, which seems to have had seven pairs of sharply pointed walking spikes and seven tentacles ending with snappers that may have included independent mouths. Evidence suggests that these unique animals were probably scavengers. There is also a very early chordate fossil, possibly related to the ancestor of fish.

What triggered the increase in faunas at the end of the Precambrian? One of the most popular explanations is an increase in oxygen levels. A study of the faunas in the Black Sea, where the anaerobic conditions in deeper water are similar to those that would have occurred with a lower oxygen level, suggests that the change in diversity of faunas may have been caused by lower oxygen levels. Some doubt about the truth of this conjecture has, however, been expressed. The idea that stromatolites may have provided the food base for the higher organisms is also open to some doubt because the decline in the stromatolite population does not seem to be linked with the increased

diversity of faunas in any way. In general there is no clear explanation for the increased diversity.

Q. Is there any evidence that the eyes of the unusual animals in the Burgess Shales are facetted like those in later trilobites?
A. You can't tell for certain because the fossils within the Burgess Shales have been flattened too much to preserve this sort of detail.

The afternoon session was started by our old friend Denis Bates from the University of Wales at Aberwystwyth. Denis took us through details of the structure and evolution of some of the more unusual graptolites found in Wales and elsewhere.

Graptolies are rather enigmatic creatures because, having no modern relatives or analogues, we are unable to use observation of present day species to fill in details of their life cycles. They are small colonial animals which normally consisted of a sexually-reproduced ancestral sicula from which a succession of thecae was budded. Many specimens have been completely flattened during burial, but a few have been preserved in environments that allow us to study their three-dimensional structure.

Dendroids were a type of graptolite found in complex colonies, looking rather like branching seaweeds, which were attached to the seafloor by their cylindrical sicula. They first appeared in the Middle Cambrian and didn't die out until the Carboniferous. On dendroids two types of thecae (autothecae and bithecae) on each branch are connected by means of a stolon.

In contrast, graptoloids have conical siculae, no stolon and only one type of theca (the autotheca). Also they did not grow attached to the seafloor, but were either planktonic or nektonic. These changes represent a simplification of the structure of the graptolites, which was paralleled by an increasing symmetry within the genera. The most advanced forms of symmetrical graptolite development were the spiral monograptids, in which individual thecae changed in size and shape depending on their position on the curved stipe.

The more unusual graptolites which Denis has been studying under the scanning electron microscope at Aberwystwyth have many features similar to those found in the dendroids, but the cortical layer, instead of being of constant thickness as in the dendroids, is seen under the microscope to have been laid down as a series of strips (bandages). A set of slides showed how the change developed from the constant thickness of the dendroid and the ordinary graptoloid to the full bandage affect, and how this affected the other parts of the graptolite. The most noticeable overall change this produced was as increase in the flexibility of the graptolite structure. As these more unusual graptolites are associated with shallow water deposits it is likely that these changes allowed the graptolites to cope with the more turbulent conditions to be found in shallow water environments. There is also evidence from the position of the unusual graptolites within the stratigraphic column that the changes shown in the slides occurred more than once during the evolution of the graptolites, different genera making the same evolutionary step to allow themselves to exploit what was, for them, a new ecological niche.

Denis Bates' talk was followed by Professor Chaloner of Bedford College, London, talking on the Land Migration of Plants.

One of the greatest adaptive attainments during the course of plant evolution was the step from the water onto land. Its importance is shown by the fact that this was probably the only biological event that would have been evident to an observer from outside the solar system. Plants preceded animals onto land, so creating the protected niches that the animals were able to adapt within later. Among the earliest plants recorded are those in the 1800 million year old Gunflint Chert, which contains small filaments a few microns across made up from a few closely-spaced cells resembling a stack of coins. These are characteristics of blue-green algae found throughout the Precambrian and later ages, and the present day.

The next noticeable change in the evolution of plants was not recorded until the Ordovician. By

then the algae had developed a high level of morphogenetic control, giving a programmed pattern of growth, so that one part of the filament went upwards whilst another part branched out to catch the light for photosynthesis. It was not until the end of the Silurian, in the Downtonian, that the first plants appeared, of the genus *Cooksonia*, which showed structural characteristics that indicate that they were living in air rather than water.

On Rhynie Muir in Aberdeenshire, Lower Devonian chert has been found to contain plants that were growing in a marsh or bog-like environment near a volcano. The volcano periodically sent out fumaroles which killed the plants almost instantaneously and then silicified the remains without seriously damaging them. These 20cm high, undifferentiated, sporangia-bearing plants, known as *Rhynia*, show all the characteristics of land plants, namely: an intercellular space system connected to the air outside through stomata; the spiral-celled central water-conducting strands (xylem); the water-retaining cuticle over the upper surface of the stem, and spores for propagation. The stomata allow air to penetrate the plant tissue during photosynthesis but are closed off whenever water is scarce to prevent evaporation. The spores are coated with a resistant coat of sporopollenin, as used by modern plants, that allow the spores to become tough enough to be borne on the wind for dispersal. This also requires them to be small enough to be picked up by the wind. For *Rhynia* this results in a 30 micron spore size. The spores have the characteristic Y shaped cleft that defines where the spore will split open. This Y shaped print is the result of the spores being formed in fours, so that each spore shows a facet left by each of its three neighbours. The three way split indicates that *Rhynia* had developed the haploid/diploid characteristics of modern land plants.

The Silurian *Cooksonia* also had two of the four main features so well demonstrated by *Rhynia* - elongated cells similar to xylem and primitive spores with a Y mark on it. The earliest Wenlockian in Ireland has also provided a possible predecessor for *Cooksonia*, but in this case no spores have been detected. *Cooksonia* seems to have had a fairly wide distribution, as evidenced by the spores found in many Silurian sediments around the world, most of which belonged at this early stage to just one or two types.

It is likely that the first necessity of plants that were to migrate onto land was that they started with spores that could be transported on the wind. After this it is thought that the water-retaining cuticle was developed, to allow the plant to survive out of water, and alongside this the water-conducting xylem would be needed to get the water supply up the plant's stem.

The Rhynie Chert gives us evidence that even in this early stage of development plants were subject to attack by fungi. It may be that the fungi were symbiotic or saprophytic (ie attacked only the dead plant), or they may have been an early form of plant disease, or perhaps, at this early stage of development, there was some other link, or a combination of links, between the two species. Unfortunately we cannot resolve the real nature of this relationship from the fossil material.

As soon as animals took advantage of the moist, shady environment supplied by the plant cover they started to attack the plants which provided them with a primary food source. Anthropods, including mites and other 'non-insect' early land dwelling animals are the first creatures that we know attacked plants. One of the anthropodic arachnida (a spider) has been found fossilised sitting inside an empty sporangium of *Rhynia*. Modern arachnids, if unable to find any prey, will also eat spores, which provide a high-protein food source. The plants would have been relatively happy about this because some of the spores would have been scattered by the eaters, so helping to disperse the spores of the plants. This habit was the start of a plant/animal relationship which ultimatley led to insect pollination of the plants. There is also some evidence of *Rhynia* being 'tapped' by animals, possible arachnids, for their sap.

Only the green algae were successful in colonizing the land, and all other plants have developed from this one phylum, whereas many different phyla of animals have been successful in becoming established on land. This could be because there is only one way for plants to behave, to stand still

and photosynthesise, whereas animals can use differing means of obtaining food. The red and brown algae were never able to move permanently onto land.

It is evident that plants increased in size between the Devonian and Carboniferous as they competed for light with other plants. Small spores became unable to cope with the problems of germinating in the shade of other plants as they contained too small a food supply to support the growth of a new plant in the diminished light. By Late Devonian times plants like *Archaeopteris* had developed large female spores containing a food supply, whilst retaining small male spores that could be easily transported. Sexual differentiation had raised its ugly head, leading to true seed propogation by the end of the Devonian. Each seed contains one large megaspore at its core, containing a large food supply (which also provides animals with a high-energy food source).

We are still uncertain if *Rhynia* developed from algae found in intertidal conditions or whether it developed from algae already partly on land but located in moist habitats such as are provided by waterfalls. It is also uncertain what came between the algae and the obviously vascular plants that were evidently land dwellers. All in all, we still have a lot to learn in this field.

Q. How do seaweeds differ from the smaller algae and vascular plants?
A. This would require a further lecture! The main difference is that the seaweeds, like all algae, rely on water to disseminate their eggs and sperm. Brown algae are more common than green algae in the sea, the latter probably being freshwater rather than saltwater derived.

Q. Where do bryophytes (liverworts and mosses) fit into this scheme?
A. If you watched David Attenborough you would think that they were the missing link between the algae and the vascular plants. The first fossil bryophytes, however, do not occur until well after *Cooksonia* and *Rhynia* came on the scene. The bryophytes seem to be a sidetrack that did not fully develop into higher plants.

Professor Chaloner was followed by one of his former students, Andrew Scott, now based at Chelsea College, London, and specialising on the development of Late Palaeozoic terrestrial ecosystems. Most of the data we have concerning Devonian animals and plants comes from the Old Red Sandstone facies, mostly derived from the Old Red Sandstone continent of the northern hemisphere. Wales, Scotland and New York State provide particularly good sources.

Until there was life on land the continental areas suffered from unchecked erosion of all upland areas. Early colonisation of the land seems to have started in low-lying areas that were not subject to erosion and were near water. Typically flood plains and point bars of meandering rivers would have seen the first plants to reach the land.

Most of the Lower Devonian plants were small, normally less than one metre tall, and were not differentiated into the leaves, stems and roots we associate with plants. It is not until Mid to Late Devonian times that we observe the development of leaves, though by the end of the Devonian they were fairly common. Large leaves provide a better area for photosynthesis and also shade competing plants from their main energy source, the Sun. Shade is very important in plant growth, as can be seen in primary forest areas, where the cutting down of the major trees allows the previously non-existent underbrush to cover the forest area.

Plants could not reach great heights until the technique of secondary growth allowed them to increase in width with age and increased height. Previously only the initial primary growth could be used to support all subsequent development. This change allowed a two tier ecosystem to develop by the Late Devonian, one tier being the forest canopy and the other being the forest floor. The shaded forest floor provided the cool, moist conditions needed by the early terrestrial animals.

It was not until the introduction of true seed propogation that plants were able to move away from the moist environments they developed in. By then the seed contained enough food supply for the plant to start its life cycle without needing nutrients supplied from the soil with the water.

A factor affecting the development of plants was lightening-induced forest fires. Fossilised evidence in the form of fusee deposits have been found in Late Devonian and Carboniferous sediments. These prove that the oxygen content by this time must have been at least 30% of the current level (otherwise the fires could never have started). The fires would have cleared areas which fresh plants could colonise, probably stimulating the development of plants that could be quickly propagated.

One perhaps surprising element in the fossil record is the gap between the development of the forest canopy in the Late Devonian and the first known flying insects in the Namurian of the Carboniferous. This may be because only a few flying insects have been preserved, or it may reflect the time it took insects to adapt to this new environment.

Devonian flora seems to have been very undifferentiated, the same plants being found in almost all regions, but during the Carboniferous differentiation becomes evident. This paralleled the development of the seed plants, and may reflect experimentation by the seed-producing flora seeking the most efficient type of seed.

By Coal Measure times, with its tropical steady-state climate in what is now the northern hemisphere (and little record in the old southern continent), we find many spores preserved in the fossil record which can be correlated to known plants, allowing us to plot the distribution of plants where no complete remains have been preserved. Some plants obviously arrived suddenly on the scene, others gradually became more common: some died out quickly, whilst others have survived to the present day.

A good source of information for Carboniferous plants are calcium carbonate impregnated coal boles that formed early in the fossilisation of the peat that became the Coal Measures, at a stage where all the cellular details of the plants making up the peat could be fully preserved. America provides large numbers of these coal boles, which are studied in much detail.

Looking at a reconstruction of a typical Carboniferous Coal Measures landscape we see a swampy, low-lying area where meandering rivers cross to a delta by the sea. The river enters freshwater lakes at various points, forming a shallow-water mini-delta as it does so. The rivers also produced sand bars, etc, and so provided a variety of environments in which different groups of fauna and flora could live.

The fossil evidence suggests that very few of the Late Carboniferous land vertebrates were herbivores. Most of them were carnivores, living on other vertebrates or on the herbivorous arthropods. Some of the arthropods, such as the millipede-like *Athraplura*, grew up to two metres in length. Others were large flying insects similar to the dragonflies of today, many of which had wings that closely resemble the local plant leaves, as the British Museum found out in a recent survey of its wing collection! The early land vertebrates only seem to have used the plants for shade and as cover when waiting to pounce on their prey.

The Coal Measures were dominated by the lychopods during the Westphalian, but these died out during the climatic change that marks the boundary between the Westphalian and the Stephanian. Their place was taken by the tree ferns, which can survive in drier climates. By the Namurian we have evidence that there were extensive upland floras which stabalised the soils in areas providing the sediments for the low-lying areas. These upland floras include the early conifers. By the Permian the conifers had spread to the low-lying areas, indicating that they had finally dried out. The fauna associated with the conifers include many herbivorous mammal-like reptiles, the first of the herbivorous land vertebrates. It is important to note this association of changes in the habit and habitat if we are to progress further in the study of ancient terrestrial ecosystems.

Andrew Scott was followed by Professor Doug Shearman of Imperial College, London, who talked about the Ancient Evaporitic Environments which are very closely linked to the major oil provinces around the world.

In the Devonian Stetlar formations of Alberta and Saskatchewan we find from boreholes that to the east the facies in Saskatchewam are the traditional Devonian continental red beds, and that these change to anhydrite and then to a dolomite and anhydrite mixture near Calgary before finally becoming an open marine limestone in the west of Alberta. The dolomite/anhydrite interdigitates with the limestone, with as many as thirteen interdigitations occurring in 50ft of sediment, but at one point in this dolomite/anhydrite sequence there is a large lens of limestone. This marine wedge, being capped by the airtight anhydrite bands, provides a good reservoir for the gas and oil found around Calgary.

To the southeast of Saskatchewan and in North Dakota a similar sequence occurs in the Missisipian (Carboniferous) deposits, with oolitic limestones followed by dolomitic carbonate muds and nodular anhydrite. The cycles here are up to 100ft thick, providing large limestone oil reservoirs. Some of the cycles show distinct erosion surfaces at the top of the anhydrite. There is an unconformity above this sequence, which is followed by Mesozoic desert-produced sandstones. These later rocks have altered the top of the limestones, providing yet another cap for the limestone oil reservoirs. In both these provinces, however, there is no evidence of any bar structure that could have resulted in the sort of salinas in which we often see gypsum being deposited today, so another explanation is needed for the formation of the anhydrite.

Looking at the oil-bearing strata in the Persian Gulf we can see the same sequences, with algal mats being evident below some of the anhydrite deposits. Looking at the present day Gulf shoreline we can find the same sequence of deposits in the recent sediments along the coast of the United Arab Emirattes. Behind the shoreline there is a supra-tidal area, called a sabkha, up to 20 miles wide, which is only flooded when storms coincide with spring tides. The lagoons in front of these supra-tidal flats are very shallow, often going out many miles, and algal mats are found at the top of the intertidal zone.

Digging into the sabkha you soon reach old algal mats, with lagoonal carbonate mud deposits below them, which indicate that the Gulf is silting up at a rate of about 1m/yr. Around these mats pure white anhydrite is deposited in nodular masses, which can often be seen to have coalesced together to form what look like beds. In places the anhydrite forms a diapir very like a salt dome. The anhydrite has been precipitated interstitially from groundwater, pushing the host sediment aside. The groundwater in this low-lying area is a saturated brine. Interestingly the anhydrite only seems to be formed above the rest level of the groundwater, capilliary action drawing up the salts to where they are precipitated. Below the groundwater level the hydrated form of calcium sulphate, gypsum, is being formed.

Sabkha-type deposits have been found in the Jurassic Purbeck formations under Sussex, Surrey and Hampshire, where they are now mined for their anhydrite and gypsum. *(See the last Journal - Ed.)* Algal mats can easily be seen in these formations, and in places the nodular nature of the anhydrite can be identified. The erosion surfaces in these deposits were probably the result of erosion caused by storm-driven floods similar to those caused in the Gulf today by the Shimal, whose hurricane-force winds can be seen to strip 2-3 inches of sediment from large areas of sabkha in just a few hours.

The limestones forming the oil reservoirs associated with these sabkha deposits are highly porous, oolitic, pelitic, carbonate sands. In places these open marine limestones also contain crystals of anhydrite, which can form nodules or nodular bands. The anhydrite forms in the porous cavities within the limestone during its burial, so reducing its oil-bearing potential. Sometimes the expansion is enough to seal the limestone completely, forming a new cap rock. The anhydrite can also replace much of the original carbonate material in the limestone, turning the original calcium carbonate to calcium sulphate, with a resulting 25% increase in volume. If the anhydrite is later dissolved away, however, the porosity of the resultant rock will be higher than that of the original limestone, so increasing the oil-bearing capacity.

Q. Do you know anywhere in the Mediterranean where there might be deep basin evaporites?
A. Many of the Hercynian evaporites in the Mediterranean are obviously sub-aquatic deposits. Many of them, however, contain blue-green algae that suggest they formed within the photic zone.

Q. Has the saturated brine groundwater been found to be depleted in sulphate and calcium and relatively rich in sodium and chlorite?
A. It has. The brine is so saturated that when exposed to air in a pit it will start to precipitate out within half an hour. The calcium level is the first to drop, with a subsequent rise in magnesium. Later the magnesium level also starts to drop as the surrounding limestone is dolomitised.

Sunday morning started with a talk by Tim Palmer of Oxford University on Faunal Community Evolution on Hard Substrates. There is quite a lot of information now available about many of the species/genera in the fossil record, and it is possible to obtain a good idea of the relative numbers of fossils in the different ages. When plotted on a graph such information seems to imply that there were evolutionary peaks, but care must be taken when interpreting these results. For instance, it is likely that as some of the rocks have been studied more than others they will show a greater diversity of species. This is particularly likely to be true of the Mesozoic strata, particularly in view of the large number of universities in the south of England which have geologists studying these strata! Similarly, certain faunas are found to be very well preserved in certain locations and are, therefore, studied in great detail. An example is the abundant brachiopod fauna preserved in the Permian rocks of West Texas. Taxonomic oversplitting can also lead to an apparent increase in the numbers of species.

The interpretation of the implications of these graphs is also open to question. Some geologists have claimed that the graphs reflect properties of the evolutionary process. They could equally well, however, be interpreted as reflecting changes in the areas of the relevant habitat required for each species. These areas are affected by the relative positions of the land masses in each era, and by the height of the sea. This latter is particularly relevant because the majority of species we have a lot of data on are shelf-living marine animals. These factors have been used to explain the decrease in the numbers of species in the Permian, when the supercontinent of Pangaea was formed.

To distinguish between these two interpretations it is necessary to restrict the area considered, so that instead of taking all species and environments we consider only one commonly occurring type of environment. We can then compare the communities occurring in that habitat during the different periods. To do this it is essential to be able to distinguish accurately between the different types of environments, using some abiotic identifying feature whose range is relatively limited and well understood. Oolite shoals are one precisely controlled group that could be used in this way, but such shoals provide very poor living conditions and so only provide a home for a very few species.

A better habitat is offered by what are known as hardgrounds. Hardgrounds arise when the soft sediments making up the seafloor are cemented together with $CaCO_3$ deposited from the sea water percolating through them. Good environmental control can be obtained by studying only those hardgrounds that can be identified as having formed in a shallow shelf-carbonate sequence of the type deposited in tropical latitudes. The cementing precipitate in this environment is normally either aragonite or magnesian calcite, and the sediments are only formed in relatively low energy areas, where they are not disturbed by the currents percolating the water through them. Hardgrounds are often formed as layers within sediments, later becoming exposed due to subsurface erosion.

The nature of these exposed hardgrounds is such that principally boring or encrusting life forms colonize them. The boring animals leave obvious traces, but can sometimes be confused with fossilised burrows that were in the soft sediments before they were cemented into hardgrounds. The borers develop their holes in the hardgrounds either physically or chemically, whereas the

encrusters cement their shells onto the hardground, as barnacles do today.

Looking at how the types of fossils found in hardgrounds have changed with time we see a marked increase in the rate of species diversification between the Cambrian and the Ordovician, with another step in the Jurassic. There is no evidence of the steady increase in species diversity predicted by some evolutionists. There is, however, evidence that the types of fossils in the Palaeozoic are different from those in the Mesozoic, where brachiopods, worms, bivalves and boring sponges became much more common.

It is interesting to see how far these changes are due to a change of ecological niche. All hardground species are filter feeders, but some feed close to the substrate (eg barnacles) whereas others reach a long way for their food (eg crinoids). There is no evidence, however, that one feeding level predominated over another during any geological period.

An obvious difference between the Palaeozoic and Mesozoic, however, is an increase from 10% to 40% in the proportion of boring animals making up the fauna. For the encrusting species there is a parallel change in the proportion of species with protective exoskeletons rather than the purely supportive endoskeletons used by most Palaeozoic species. Both these factors can be explained by the rise in the numbers of marine predators over this period.

There is still a lot of data to be collected, particularly for the end of the Palaeozoic, but the evidence so far available underlines the problems associated with adopting the concept of uniformitarianism in palaeontology, because similar physical environments do not necessarily correlate with similar biotic environments.

Q. Do you think that when Late Palaeozoic/Early Mesozoic hardgrounds have been studied you will find that the predators developed any later than the Permo-Triassic period suggested by your current data?
A. Yes, it is likely that when we find some useable hardgrounds this date may come forward to, say, the Jurassic, which other evidence suggests was the main period for the increase of predatory species, rather than the Late Palaeozoic.

The next speaker, the second of the OU's representatives, was Peter Skelton, who took as his subject The Evolution of Reefs. Like Tim, Peter placed a special emphasis on the dangers of applying a strictly uniformitarianist approach when trying to reconstruct the communities of the past.

A complex web of interactions exists between species and the surrounding environment in a living community, so interpreting the workings and environments of ancient communities, with their biased and partial fossil record, is very difficult. Uniformitarian analogy with modern communities helps to plug some of the gaps in our knowledge, but we know that the Earth's surface and its inhabitants have undergone much change, so we should also be on the look-out for differences between ancient and modern. Reefs and reef-like 'buildups' provide a useful test of the value of uniformitarian analogy because their fossil record is relatively good, leaving us in less ignorance as to their evolutionary history than with most other types in the community. As with hardgrounds, many reef organisms have resistant, shelly skeletons and live attached to the seafloor. They thus stand a good chance of preservation in life-position, and relationships between them can readily be discerned.

Modern tropical reefs consist of a framework, mostly of corals, bulked out by shell hash and bound together either by encrusting organisms such as calcerous algae or by carbonate cement. Reef-building corals only thrive in relatively clear, warm, shallow water of normal marine salinity. This is due in part to the symbiotic association of the corals with the single-celled algae that live in their tissues. These algae need light to survive.

A typical feature of coral reefs, whether atolls, fringing or barrier reefs, is a prominent wave-resistant reef crest. This crest isolates the waters behind the reef from the action of the open ocean, and this often leads to changes in the salinity and temperature of the water within the lagoon which

are inimical to the corals and their associated organisms. The form and distribution of the reefs thus reflects subtle interactions between the character of the constituent organisms and the prevailing physical conditions around the reef.

How useful are these modern reef as analogies for reconstructing the forms and environmental contexts of ancient buildups? Cretaceous buildups provide a particularly good test because this period has an ample, well studied fossil record in the form of buildups dominated be a now extinct group of organisms superficially resembling corals - the rudists.

Looking at the Cretaceous geography we find that the configuration of the oceans and continents was such that climates were warmer than today (there were no icecaps). Also, sea level rose to 600m or more higher than today's levels, inundating vast areas of continental crust with shallow seas. Tidal and wave action in these semi-inland seas must have been relatively damped in comparison with that on most modern shelf-seas, which tend to face out into deep oceans. Evaporation and run-off from the land into the shallow seas evidently led to wide variations in their salinities. Scattered through these seas, particularly those flanking the meridional Tethyan Ocean, were numerous buildups, often dominated by rudists. Many of these buildups seem to have been tolerant of the abnormal salinities.

The earliest (Late Jurassic) rudists were associated with coral patch-reefs. They grew as spirally-coiled, oyster-like 'encrusters', either on lime-sand surfaces or on hard substrata such as shells and coral stems. Near the beginning of the Cretaceous some of the rudists evolved the ability to uncoil with growth, so as to grow upwards in tubular fashion from the substratum. This was possibly an adaption to overcrowding. Their descendents exploited a wide range of conditions. The 'elevators' emphasised vertical growth, and could spring up rapidly from scattered shell fragments on muddy seafloors, while 'recumbents' emphasised horizontal growth - their low, spread-out form resisting strong current action on winnowed, lime-sandy substrata.

Buildups made by Late Cretaceous elevators are commonly found with their rudists in life position. They grew in shallow, sheltered, calm water on muddy seafloors, and show little or no surrounding halo of debris. Although they were fairly solid structures because of their closely packed growth, the associated sediments show that wave action would have been largely foreign to them.

Some Middle Cretaceous recumbents can be shown to have infested the foreset slopes of very shallow, current-swept lime-sand (grainstone) shoals. They have usually been tumbled after death and the fossil shoals lack evidence of early binding, indicating they were, technically, banks. Some recumbents could also grow as faculative elevators, forming tangled, bushy patch reefs rising from the seafloor just beneath the level of traction currents created by normal waves. These early recumbents rarely built true wave-resistant structures, though their buildups formed striking linear features along the rims of carbonate ramps or platforms such as those found under southern Texas. Although in a similar position to modern barrier reefs their sedimentological and palaeoecological characteristics show that they generally lacked the robust crests projecting into the zone of wave surge that is so typical of modern reefs. Some of the specialist recumbents of the Late Cretaceous formed buildups in which the rudists have been preserved in life positions, despite a lack of original binding and evidence of their having been subjected to traction currents, which probably indicates that they had become truly wave-resistant.

Thus we have solid, superficially reef-like, rudist buildups which rarely even experienced wave action, barrier-like banks that did, but could not resist it, and buildups which did resist it but cannot be called reefs because of their lack of early binding. The problems encountered in classifying and interpreting such buildups results in no small part from a nomenclature that is obsessively rooted in the particular characteristics of modern reefs and the conditions in which they grow. The rudist buildups of the Cretaceous are, however, best understood on their own terms by constructing models of them based on detailed studies of their sedimentology and palaeoecology. Uniformitarianism, though useful at the level of basic

processes, can be positively misleading if rigidly applied at higher levels of complexity, such as when trying to interpret the ancient communities that formed buildups.

After coffee Dr. Bob Savage of the University of Bristol entertained us with a talk on Continental Drift and the History of Mammals. Continental drift is rather an unused term today, but 32 years ago it was favoured by biologists who wanted to explain the distribution of the animal species, though the concept was not accepted by geologists! In the 60's things changed dramatically, geologists began to accept the concept and, relating it to a causal concept, called it plate tectonics.

The concept of continental drift goes back to the 1850s, when Schnieder produced a map which explained the distribution of Carboniferous plants in the southern continents. The concept doesn't appear to have surfaced again until Wegner, in the early decades of this century, produced further evidence for continental drift.

The earliest mammals discovered to date occur in Late Triassic rocks, from just about the time that the supercontinent Pangaea was breaking up into Gondwanaland and Laurasia, with the Tethys sea between them. The continents were probably still connected at this stage, perhaps by an island chain. Land animals are quite useful for plotting continent distributions because they can only cross relatively short ocean stretches. Even a sea the size of the Irish Sea provides a very effective barrier; the only way across for land animals is on floating vegetation that currents can carry across. Whilst the tropics contain fair amounts of suitable vegetation only small land animals can travel far by this means.

During Late Triassic times mammal-like reptiles dominated the land-based faunas. Dinosaurs were only just appearing and there were no birds. One of the earliest animals with mammalian-type complex dentition was the rat-like *Oligokyphus*, which has been found in Somerset. It was not, however, a true mammal. The late reptiles are distinguished from the mammals by having several bones in the lower jaw and only one bone in the middle ear, against the single bone of the mammalian jaw and three in its middle ear. Animals similar to *Oligokyphus* have been found in Germany, China and South Africa (where the *Tritylodon* occurs). No similar species have been found in India, Australia and Antarctica, but North and South America both provide specimens, This shows that these species were common to both Laurasia and Gondwanaland.

The shrew-like *Eozostrodon*, which occurs near Bridgend in South Wales and in the Mendips, shows, however, a multi-boned mammalian jaw. Similar mammals are also found in Germany, China and South Africa, but there is no unequivocal evidence of similar species in the Americas. This distribution again suggests that the earliest mammals were fairly well distributed throughout Pangaea before it broke up, implying that they developed in the early or middle part of the Triassic. It should be noted that many of the earliest mammalian fossils occur in clefts in continental deposits, such as limestone potholes, which makes them difficult to date accurately.

It may seem strange that the early mammals were so well distributed at this early stage of their evolution, but small rat and shrew-like animals can fit into most niches, as their ancestors clearly show, and the world wide distribution could easily have taken up to a million years, which would only require a migration rate of about 15 yards a year!

Dr. Savage's second example concerned the distribution of the pouched mammal, the marsupials. They are found in the Late Cretaceous of North and South America, and have survived in South America to the present day. Migration between North and South America was possible from the Late Cretaceous until about the end of the Palaeocene. The marsupials died out in North America in the Miocene. Pouched mammals are known from Oliogocene times onwards in Australia, but how did they get there? None have ever been found in Asia or Africa. Anatomically the Australian marsupials could be derived from the very early American forms, but did they go the long route via Alaska, Siberia, China, Southeast Asia and New Guinea to Australia in early

Tertiary times? This is unlikely because Australia was a long way from Southeast Asia in the Tertiary, though some South American mammals, the herbivorous notoungulates, did make it to China. Another possible land route from South America to Australia in the early Tertiary was via Antarctica. We know Antarctica was in a climatic zone where life could have been supported, but we lack the evidence to prove this connection as yet: we need some fossil marsupials from Antarctica.

For his final example Dr. Savage briefly outlined the history of South American Tertiary mammal faunas. These fall into three stages. The Palaeocene-Eocene faunas contained marsupials, edentates and condylarths. In the Oligocene we see the arrival of rodents and primates, but where and how did they get to South America? They must have come by sea because the continent was isolated at this time. They probably came on floating vegetation from either Africa or North America - the distance in early Oligocene times was about the same either way, though Africa is the most exciting possibility. In the Pliocene we see the great invasion of carnivores and herbivores from North America across the new land bridge around Panama. These mammals rapidly radiated throughout the southern continent, where much of the old fauna had become extinct during the physical and climatic changes associated with the rise of the Andes.

Dr. Savage finished by pointing out that our knowledge of the distribution of the continents through time can help us to make predictions about the migration routes of mammals, and provide us with clues as to where to search for new fossils.

Many of us who read the title of the last talk in the series, which immediately followed Sunday lunch, wondered what we had let ourselves in for when we saw the word Coleoptera, but Russell Coope of Birmingham University soon put our minds to rest - its just our old friends 'The Beetles', who were being studied at Birmingham before Liverpool had ever heard of them! The title of his talk, Coleoptera as Environmental Indicators, aptly encapsulates the subject which Dr. Coope has been studying for the last twenty five years.

As an undergraduate studying geology and zoology he was told the old but still widely current story of the near extinction of species during the ice ages, with stringent selective pressures being applied in the surviving enclaves because of the inhospitable environment. He was told such conditions led to changes in the gentetic make-up of the population, and theory would have it that these mutated species could not interbreed by the time glaciation had ended. The new species then went forth to immediately make use of the now hospitable landscape in small family groups which, being pioneer groups, are isolated from contact with others, so leading to more inbreeding and, therefore, to more speciation.

The palaeontological data, however, does not support this interpretation. The beetles are the largest group of fossil insects and provide proof that, at least in their case, the classical view is not tenable. They are particularly useful because their hard exoskelteton, which is the part used in the taxonomic differentiation of live species, is the best preserved part of the fossilised animal, being hard enough for permanent preservation. The beetles are complicated animals, which means that there are many different criteria by which different species can be identified.

Looking at the Quaternary fossil record we find that the species found as fossils can easily be equated with modern species; the degree of observed difference being only that found between individuals of the same species in modern beetle collections. The main proof for this statement, surprisingly, lies in the male genitalia of the different species, which take a bit of finding among the fossil remains as they are sometimes less than 0.5mm in size. This is, perhaps, one of the few areas where applied pornography is respectable! It is truly amazing what Dr. Coope has been able to do with the contents of a peat bog, a bowl of alcohol, two matches, two needles and a piece of cotton!!

When you start to plot the modern geographical distribution of fossils identified using these criteria you soon start to see that certain species are

characteristic of certain climatic conditions, and that the geographical distributions of whole assemblages of species provide a consistent picture of climatic conditions.

Many of the species found in deposits from the period of the Devensian (Last) Glaciation in its type area near Birmingham are found today either in north Russia or on top of mountains in areas that remain frozen for most of the year. The species found in the warmest part of the Warren House interstadial are now to be found in Mediterranean countries. These beetles are found in deposits that show no signs of having been formed near the tree line so often claimed to control the distribution of animals during glaciations. In fact it is the beetles that give us the main evidence of there having been a temperate episode around 43 000 years ago.

One species found in great numbers at Dorchester-on-Thames has recently been identified, thanks to the superb British Museum collection of beetles, as being identical to a species now found only on the high plateau of Tibet, just north of Everest. Incidentally, this identification was done using a specimen brought back by the 1924 British Everest Expedition - the one that Mallory and Irvine were lost on.

When you plot the numbers of families found in glacial and interglacial times you find that, as well as the change in the types of species between the two periods, there is also a decrease in the numbers of families during the glacial periods. There is also evidence that during two of the last three interglacials the climate was typical of the oceanic temperate climate in Britain today, but that for many of the glaciations the climate was nearer the cold continental climate found in places like Tibet today. This was the period when the North Atlantic was still covered with pack ice, much as the Arctic is today, and this pack ice would have led to Britain having been surrounded by an area of non-evaporation similar to that found where continental climates occur.

To return to the evolutionary picture mentioned at the beginning, the main factor that was missed in the earlier explanations for apparent species extinction was species mobility - the ability of species to move to areas that better suit their life-styles, so apparently becoming extinct in their former locations. This also means that it is likely that there was constant interbreeding between the migrating populations, so breaking down the isolation of groups, a main cause of speciation.

Finally, it is important to realise that for only about 5% of the last half million years has the climate in Britain been as warm or warmer than it is now. The palaeontological evidence shows that there were sudden drops in temperature at the start of the glaciations, with a corresponding quick change in the type of beetles inhabiting a given area. Evidence from the Glanllynnau late glacial deposits suggests that the rate of change in temperature was about 1C per decade in mean summer temperature, and 2C per decade in mean winter temperature. This means that the change from glacial to interglacial (and vice versa) conditions took place in about the span of one human lifetime. Recent work has shown that the same rate applied to other glaciations, and that these changes are in some way related to changes in the Atlantic ocean currents that sweep our coast. Perhaps this fact can be used to give us some warning of the next glaciation!

Our president, Dennis Jackson, was handed the difficult task of summarizing the main points that the Conference had raised. It is impossible to summarize a conference as wide-ranging as this, but Dennis pointed out that there were still many areas that we are uncertain about, and many areas where the problems are so abundant that it is impossible to come up with a solution that answers all the questions. He also pointed out the recurring warnings about interpreting graphs, etc, too rigidly - they are merely simplifications.

Years ago, when Dennis was an assistant professor in Canada, he suggested at a conference that the Darwin Rise might explain the Cretaceous sea level changes, only to be told by a very eminent American geologist 'What Darwin Rise?'! Isn't it nice to see how the old ideas come back and recieve new and convincing evidence of their validity! Again Denis Bates' idea that graptolites

might have been planktonic was not accepted a few years back but is now respectable.

All in all Dennis thought it was a very good, thought-provoking and wide-ranging Conference from which all the participants gained a lot.

Anybody wanting to know more about the migration of plants onto land (see the report on Professor Chaloner's talk, pp10-12) would do well to start with the introductory guide to the subject he has produced for the Royal Scottish Museum. Entitled 'Plants invade the land', it is published by the HMSO, price £1.20 A review of this booklet will appear in the next issue.

Next year's Conference, our 10th, will be held at Reading University and will look at the changes in geological knowledge during the society's first 10 years. Booking forms will be in the Newsletter early next year. I recommend that you book your place early as it is likely that yet again we will have to turn away those who leave it too late

Martin Bryan

BOOK REVIEWS - an occasional column
Paul Clasby

The new Rocks and Fossils series of undergraduate level geological field guides from Unwin Paperbacks received a preliminary notice in the Newsletter, which made reference to the general features of the first two books in the series, which cover Snowdonia and The Weald‡. This review looks in more detail at the content and concept of these inexpensive (£3.95) volumes. Of the two, *Snowdonia* is rather more successful as a field guide, though *The Weald* has its own special virtues.

Snowdonia starts with a 24 page, rather simplistic, crash course on igneous and sedimentary processes and their products, which is followed, in contrast, by the geological history of Wales in just 4 pages - concise indeed! The 14 detailed field itineraries that follow share 70 pages. They are well illustrated with maps, sections and annotated photographs. The area covered is Northern Snowdonia, from Conwy to Dolwyddelan, where the authors have been mapping for the Institute of Geological Sciences' new survey. The book ends with a limited glossary, references, a further reading list and an index. All in all an excellent, well balanced, guide.

In contrast, *The Weald* takes 50 pages to cover the geological background and history, but the 11 field excursions share only 47 pages. These are followed by appendices, including a short discussion on the basement and its possible structures, a glossary (again limited), a further reading list and an index.

The Weald suffers as a field guide from the overgenerous devotion of resources to a synthesis of information about the area - in addition to half the pages this uses 23 of the 34 figures. This information, however, is not readily available elsewhere in precisely this form, so it would be unfair to condemn this feature. It is a pity that the field itineraries receive only one map or illustration each: this is a serious weakness as there are only two locality sketches and, in general, the visual aids are rather poor, in contrast to the admirable guidance given in *Snowdonia*. It is rather difficult to understand why an excursion to Folkestone is illustrated solely with a poor reproduction of the familiar photograph of the train wrecked by the Warren landslip of 1915.

Nevertheless, *The Weald* is still a useful addition to the geologists's anorak pocket, though *Snowdonia* does the job it sets out to do with much more precision. Both books should be required reading as an introduction to the areas covered; you should not be deterred by their price, which does not reflect on their practical value in the field.

‡ *Snowdonia*, Howell, M. F., Leveridge, B. E. and Reedman, A.J. (1981) 119 a vii, 44 figs.
The Weald, Gibbons, W (1981) 116 a x, 34 figs.

The Geology of the High Peak Line

Martin Bryan

The High Peak line runs from the Derwent Valley below Matlock to Buxton, crossing the Derbyshire Dome in the process. Beechingized, the line has now been turned into a long distance walking/cycling track. The southern end of the line provides and interesting cross-section of the Dome. This tour explores the lowest part of the line as it passes up through the succession.

The High Peak line was originally built as a horse-drawn tramway between 1826 and 1831 to link the Cromford canal to the High Peak canal at Whalley Bridge. It contained four major inclines which were worked by stationary engines and ropeways, one of which is traversed on this trip. The tramway enabled easy transport between Manchester and London for the first time, whilst also allowing the new mechanised Arkwright mills at Cromford access to supplies and markets. For this reason Thomas Arkwright was the line's main sponsor. As a side benefit the line went through one of Britains main mining areas and allowed quarries to open up along its length.

The following tour starts form the Black Rock car park (295558[1]). Site 1 is on the other side of the line from the car park.

Site 1 Black Rock

This famous beauty spot is the westernmost outcrop of the Ashover Grit cap which forms Cromford Moor. As the grit has an easterly dip the moor is the highest strata in the succession outcropped on the east side of the Dome. From it you can see Riber Castle standing on the same grit band on the other side of the River Derwent below. The line of holes in the rock are the result of the more rapid weathering of bands of limonite-rich nodules to be found in the grit.

Walking westwards up the line brings you to:

Site 2 Steeplehouse Station Quarry (287555)

After crossing the bridge that passes over the unexposed unconformity between the Coal Measure Shales and the underlying limestones (passing an old lead smelting cupola at this point) you come to the fossil hunters delight, Steeplehouse Station Quarry. This quarry contains the same band of Gigantoproductus to be found in the nearby, world famous, Shaw's Quarry. This exposure is part of the Cawdor Group of limestones, the youngest in the area, which in places is as much as 65m thick. The quarry includes some interesting partly worked blocks and ample signs of how quarrying was carried out.

Returning to the line and passing uphill another 100m you find, on your right again:

Site 3 Coal Hills Quarry (285553)

A misnamed site, this quarry is part of a reef knoll within the Cawdor Group. This quarry is particularly interesting for its veins of galena. The two main veins flank the quarry, but in between there is one major and many minor branches from these veins. Note particularly the shattered zones around some of the faults and the exposed 'pothole' near the two easily accessible lead veins.

On the way out of the quarry note the upturned tank of a saddle engine and the lower ropeway wheel of the 1 in 8 Middleton Incline, which has now to be climbed to Middleton Top Engine House.

Site 4 Middleton Incline and Engine House (276553)

As you proceed slowly (!) up the incline look out for the faults under both bridges. The first bridge carried the railway over the unexposed Gulf fault, whilst the bridge over the railway is built over a small fault. Beyond this bridge note the unconformity between the heamatite-stained Matlock Group and the ordinary Cawdor Group limestones.

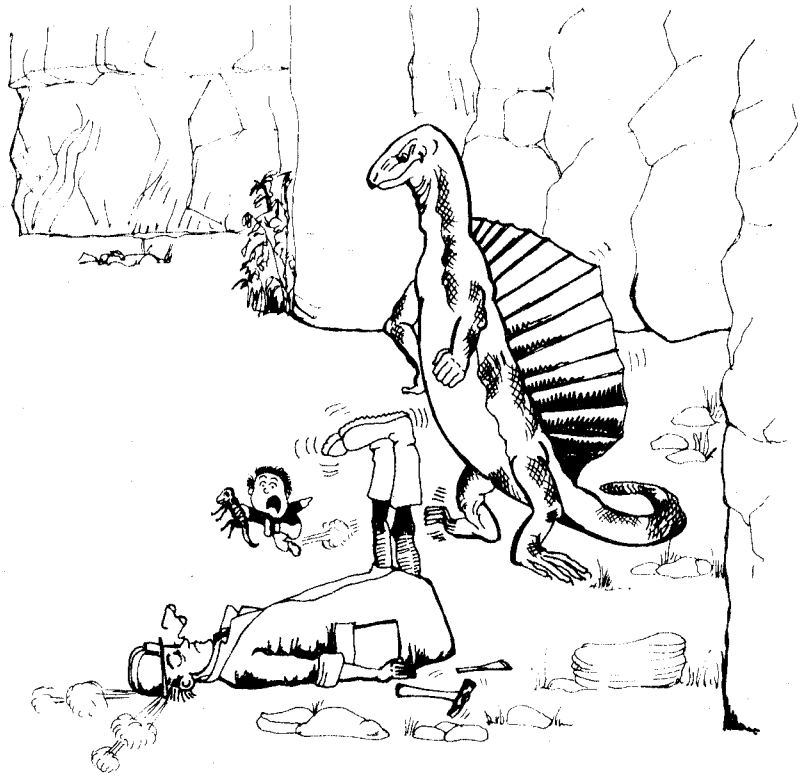
At the top of the incline is the engine house with its restored engine (working most Sundays). Just beyond the engine house is:

[1] Map references on this trip are taken from the Ordanance Survey's Peak District tourist map.

Site 5 Intake Quarry (276550)

WARNING: This quarry is dangerous - please keep children and animals under close control or leave them at the entrance. Do not go near the slurry beds. They look dry but I can assure you they are not. Also beware of the crumbly face. Everything you need to see can best be seen from a distance or in the rock falls at the foot of the cliff. IN THE EVENT OF RAIN (OR AFTER RAIN) THIS QUARRY SHOULD BE MISSED.

The points of interest in this quarry are the changes in dip from face to face, the fault zones flanking the faces and the gangue material in the falls at the feet of the faults. Also note the change across the quarry to crinoidal limestone. If access is still possible there is also an interesting view of the unconformity noted in the incline, at a point at least 30m higher. Try to work out where the fault causing this uplift is situated.



GE-ODES (or Geologists Cautionary Tales)
It is a well known fact that the sharp eyesight of children may be relied upon to find the choicest fossils. Well preserved specimens should be left in situ!

SSSI sites that have restricted access

The following list details the Sites of Special Scientific Interest (SSSIs) to geologists (and some other sites) for which permission **must** be obtained before they are visited. It gives the name and address of the person who must be contacted for such permission.

In all cases requests for permission must be accompanied by a stamped self-addressed envelope for the reply. It is unlikely that permission will be refused provided it is requested in advance, but all OUGS members must remember that hammering is **not** allowed on SSSIs (except to get specimens for projects previously approved by the Nature Conservancy Council).

Organisers and field trip leaders should always remember that permission must be received before a party from the OUGS visits any site not open to the general public, otherwise our insurance is invalid. Will all members please try to use scree deposits to get their specimens, where possible, and only hammer in situ faces where absolutely necessary.

If any doubt exists about who to contact at a site the local museum will normally be able to help. In cases of difficulty contact the Nature Conservancy Council at the address given below for East Thickley Quarry.

Pitstone Quarry, Bucks
General Manager, Tunnel Cement Ltd., Pitstone Quarry Works, Pitstone, Bucks.

East Thickley Quarry, Shildon, Co. Durham
c/o Dr. K. Duff, Nature Conservancy Council, Foxhold House, Thornford Road, Crookham Common, Nr. Newbury, Berks.

Hollows Farm, Skelghyll, Cumbria
The Owner, Hollows Farm, Skelghyll, Cumbria

Calton Hill Quarry, Derbyshire
Mr. Chapman, Estates Dept., Derbyshire County Council, County Offices, Matlock, Derbyshire DE4 3AG

Duckmanton Railway Cutting, Derbyshire
Dr. A. J. Deadman, Conservation Officer, Derbyshire Naturalists Trust, Estate Offices, Twyford, Barrow-on-Trent, Derbyshire DE7 1HJ

Charlbury Quarry, Dorset
Mr. P. Diment, Puddledock, Sutton Poyntz, Preston, Weymouth, Dorset

Upper Hale Gravel Pit, Hampshire
PSA, Blandford House, Farnborough Road, Aldershot, Hants GU11 2HA

Rudge End Quarry, Herefordshire
The Secretary, Hereford and Radnorshire Nature Trust, 25 Castle Street, Hereford HR1 2NW (Hereford 2307)

Redbournbury Chalk Pit, Hertfordshire
Mr. D. R. Pannell, Contract Gully Cleansing Ltd., Brownfields, Welwyn Garden City, Herts.

Baker's Hole, Kent
Mr. N. Lowe, Southern Area, Associated Portland Cement Ltd., Northfleet Works, Northfleet, Kent

Browns Hill Quarry and Railway Cutting, Leicestershire
The Secretary, Leicestershire and Rutland Trust for Nature Conservancy, 1 West Street, Leicester LE1 6UU

St. Ives Head, Charnwood Forest, Leicestershire
Mr. A. Ward, John German and Son, Rectory Place, Loughborough, Leics LE11 1UR

Charlton Sand Pit, Greenwich, London
Borough Engineer. London Borough of Greenwich, Churchill House, Greens End, Woolwich, London SE18

Lincoln Hill Quarry, Shropshire
Mr. J. Derry, Limeburners, Lincoln Hill, Ironbridge, Telford, Shropshire

Sheinton Brook, Shropshire
Mr. F. Preece, Brook Farm, Sheinton, Cressage, Shropshire

Upper Millichope Stream Section, Shropshire
Mr. G. Elliot, 15 Beamsbridge, Munslow, Craven Arms, Shropshire

Ashfield Brick Pit, South Yorkshire
Public Relations Officer, British Steel Corporation, Rotherham Works, Rotherham, S. Yorks.

Stairfoot Brickworks, South Yorkshire
Mr. A. Winlow, Yorkshire Brick Co., Barnsley, S. Yorks. (Barnsley 2453)

Seale Chalk Pit, Hogs Back, Surrey
Dr. A. Lindley, Flat 4, 94 Pepperharrow Road, Godalming, Surrey (Godalming 7351)

South Elmsall Quarry, West Yorkshire
Mr. A. Rees, Executive Director (Environmental Planning), West Yorkshire Metropolitan County Council, Chantry House, 123 Kirkgate, Wakefield, W. Yorks. WF1 1YG

Swindon Great Quarry, Wiltshire
Thamesdown Borough Council, Swindon, Wilts.

Cwm Craig-ddu Quarry, Brecknock
Mr. C. Cornell, Estate Office, Glanusk Park, Crickhowell, Powys NP8 1LP (Crickhowell 810414)

Carmel Head, Gwynedd
Mr. Roberts, Mynacholy, Llanfairynghornwy, Gwynedd (Llanfacthu 237)

St. Abbs Head, Berwickshire
Mr. T. McCrow, Northfield House, St. Abbs, Eyemouth, Berwickshire

Archanarras Quarry, Caithness
Nature Conservancy Council, Old Bank Road, Golspie, Sutherland

Banniskirk Quarry, Caithness
Mr. J. Mackay, Banniskirk Mains, Halkirk, Caithness

Nandt, Caithness
Call at the house on the left of the track leading to Nandt Farm to get permission

Southerness Coast, Dumfrieshire
Captain J. Blackett, Arbigland, Kirkbean, Dumfries

Ravengill, Lanarkshire
Mr. K. Wilson, Estella, Leadhills, Biggar, Strathclyde

Boyleston Quarry, Renfrewshire
The Secretary, Ferneze Golf Club, Ferneze Avenue, Barrhead, Glasgow (041 881 1519)

Petershill and The Knock Quarries, West Lothian
Mr. J. Reid, Ballencrieff Mains Farm, Bathgate, W. Lothian (Bathgate 52854)

This list has been prepared from back issues of the NCCs *Earth Sciences Conservation*. The permission of the NCC for use of this information is gratefully acknowledged.

Branch Reports

Wessex Return to Wales

Over the Mayday Bank Holiday twenty OUGS members visited Dolgellau Youth Hostel for a second Wessex in Wales session under the leadership of its warden, Graham Hall.

After a talk on the planned visits late on Friday night, Saturday's excursion was devoted to a study of the Cambrian succession of the Harlech Dome. From the first stop at Llyn Cwm Bychan a brisk walk up the Roman Steps brought the group to a fine exposure of Rhinog Grits in the crags below Rhinog Fawr. The proximal turbidite origin of the sediments was discussed, and the graded, parallel laminated, cross laminated and mud and silt units were identified within the sequence. Of particular interest were soft sediment deformation structures in the mud and silt units, interpreted to be the result of dewatering.

After a journey south along the coast to Barmouth the vehicles were parked near the Panorama Walk and a path followed towards the headland of Garn. In an outcrop of Gamlan Shales a bedding surface with prominent rippling attracted attention. This was shown to be of tectonic rather than sedimentary origin and was related to the strong vertical axial planar cleavage developed in the north-trending coastal anticline at this point.

An examination of the Barmouth Grits outcropping on Garn revealed turbidite sequences similar to those in the Rhinog Grits. The party then set off across country to the old Haffoty manganese mines. The ore bed, of sedimentary origin, was worked in shallow trenches. Low grade regional metamorphism has converted the original manganese carbonate to a flinty, banded rock consisting largely of the manganese garnet known as spessartite.

Returning to the vehicles the group travelled to Ganllwyd in the Coed y Brenin forest. The stream section of the River Gamlan was examined and a series of dioritic sill intrusions identified within the sedimentary succession, the most prominent of which form the picturesque Rhaeadr Ddu waterfalls. The difficulty of interpreting sill intrusions correctly was discussed as they bear a strong resemblance to grit bands amongst the shale sequence. Close study, however, shows the sill margins to be transgressive and the adjacent sediments to be thermally metamorphosed.

The excursion finished its first day with a walk up the mountain above Ganllwyd to the Cefn Coch gold mine. After obtaining galena and zinc blende samples in the mine tip members entered the old adit to see the quartz-sulphide mineral vein in situ.

Sunday dawned to torrential rain, but undeterred (*says he! - Ed*) the group travelled to moorland south of Trawsfynydd reservoir to examine an intrusion complex cutting the Llanbedr Slates in the Dolwen pericline. The presence of a central volcano above the Harlech Dome during Ordovician times has been suggested to explain the distribution of lavas and pyroclastic sediments in the surrounding areas. This intrusion, including as it does both acid and basic rock types, may have formed a feeder vent for such a volcano.

By late afternoon the weather had improved and the group moved to Tan y Grisau to examine the Tan y Grisau microgranite intrusion and its metamorphic aureole. The contact of the microgranite with the overlying hornfelsed Tremadoc Slates was seen at several localities. In the disused Ffestiniog Granite Quarry the contact was seen to be sharp, with xenoliths crowding the marginal zone of the intrusion. Near the dam of the Tan y Grisau reservoir, however, the contact was more diffuse, with granitisation of the country rock occurring over a zone of several metres.

Following the private road towards the upper reservoir of the pumped storage scheme the succession of hornfelses in the aureole of the microgranite was examined. Prominent spotting occurs in the rocks. It has been shown that the slates were initially metamorphosed to the hornblende hornfels facies, with the growth of cordierite and andalusite porphyroblasts, but these crystals have been psuedomorphed by chlorite and sericite during retrograde metamorphism under the effects of late stage volatiles released from the cooling intrusion.

It was then decided to shelter from the adverse weather by visiting the Llechwedd slate mine in Blaenau Ffestiniog. Members greatly enjoyed descending the underground incline to tour the working chambers of the mine. At the risk of offending the official guide the leader took the opportunity of pointing out the orientation of the main slaty cleavage, which dips northwards at a shallow angle sub-parrallel to the bedding (*so stunning the guide to silence! - Ed*). This structure, called the S_1 cleavage, is thought to be related to the early regional doming of the area during the Caledonian earth movements. A near vertical second S_2 cleavage, used by the miners to remove blocks of slate from the working faces and known by them as the 'pillaring', is axial planar to minor north-south folds superimposed on the Harlech Dome at a later stage.

Monday began with a visit to the village of Capel Hermon to examine the Coed y Brenin porphyry copper deposit. This disseminated ore body is related to the Rhobell Fawr volcanic centre active in late Tremadoc times of the Upper Cambrian. In the first outcrop seen the mineralisation affected the Ffestiniog Flags which had underlain the volcanic centre; large crystals of iron pyrites and smaller grains of copper pyrites were plentiful. The second outcrop studied showed diorite, which had formed part of the sub-volcanic complex, heavily decomposed to sericite by the hydrothermal action responsible for deposition of the copper ore. Copper pyrite at this locality was mostly weathered to malachite.

By a devious route along narrow gated lanes the group reached the eastern side of Rhobell Fawr, from which an ascent of the mountain was made. In late Tremadoc times faulting took place along the eastern margin of the Harlech Dome, with folding of the sedimentary succession and intrusion of basaltic magma along the fault zone. After eruption of subaerial basalts at Rhobell Fawr the volcanic centre sank beneath sea level and was covered by the basal grits of the Ordovician succession. An interesting exposure of the unconformity at the base of the basalt sequence was seen at the bottom of the mountain, with steeply dipping Upper Cambrian shales overlain by near horizontal basalts. During the ascent some basalt flows were observed to have brecciated zones; these were interpreted as auto-breccias formed by the cooling at the surfaces of the lava flows as they advanced. Near the summit the upper unconformity between the basalts and the basal Ordovician sediments was seen.

Graham Hall

Other Wessex Trips

On 11th April Dr. Alan Insole of the Museum of Isle of Wight Geology took 3 Wessex branch members to Alum Bay, Headon Hill and Colwell Bay. (The other 18 members missed a good day!) Starting from the erosion surface of the Chalk, where clay can be seen filling potholes, we followed the sequence down to the Bagshot Beds. The Reading Beds, which are mottled red and grey here, were formed in freshwater basins and, therefore, differ markedly from those in the Poole area, whilst the London Clay shows two shallowing marine cycles before the freshwater Bagshot clays and sands were deposited.

Since the intervening beds are largely obscured we resumed the sequence at the Headon Beds outcropping on the cliff below Headon Hill. These freshwater clays and sands include some lignite horizons in which mammal remains have been found. A large cliff fall here had exposed a lignite horizon not previously seen. The Osborne Beds proved most unusual, being a calcrete. There is a progression from lime mud at the base, through small limestone nodules, to hard fine-grained limestone at the top. This lithology formed because the lime mud dries out at the top and $CaCO_3$ in solution is drawn out by evaporation and capillary action. Dr. Insole's work has led him to believe that there was a transform fault along the Channel, passing through the Isle of Wight, which was active during Tertiary times.

On May 10th John Cowley, Minerals Resources Officer for Dorset, led a party from several OUGS branches on a field visit in Portland. We gathered in the car park overlooking Chesil Beach, where John explained the formation of this famous tombolo, which stretches from Bridport to Portland. During the Pleistocene the sea level was considerably lower than today, and rivers draining the high land behind Weymouth laid down sheets of gravel over the low land of Lyme Bay. As the sea level rose this gravel was pushed landwards by the sea. The Isle of Portland proved a barrier to the Atlantic 'fetch' of the waves, thus promoting the growth of the tombolo. The pebbles on the surface of the beach at present, at the Portland end, are mainly Portland chert, but those deep within the bank are of different origin.

John also spoke of the oil exploration in Dorset, which was at first concentrated on the anticlines which we could see on the mainland, and proved unsuccessful. Later work north of the Ridgeway fault showed that oil was present in faulted blocks. It seems that intra-Cretaceous faulting brought the Kimmeridge Clay south of the fault down next to potential reservoir rocks, and early Tertiary faulting raised the southern part again so that erosion of the high land provided detritus for the capping necesary to preserve the oil.

Our next stop was at Grove Cliff, where we followed the quarrymen's trackway to the beach to examine the top of the Kimmeridge Clay. Rotational slumping in the clay was contrasted with the opening of joints in the Portland Stone cliffs above. Fallen blocks were often taken to the ships for use as building stone, stone jetties on this eastern side of the island being used to load them. Working our way back up the cliff (adders permitting) we examined the West Weare 'sandstones' (actually dolomites) which showed that the open sea of Kimmeridge times was becoming restricted and shallowing. This led to the formation of magnesium-rich brines, leading to the dolomitisation of the limestones and marls which were then being deposited. Continuting upwards, along the old railway line, we saw the Cherty Beds, the massive Freestone and finally the Dirt Beds and the Purbeck Beds, indicating the progressive shallowing of a warm, restricted sea and the emergence of this area as land.

After lunch we visited Broadcroft Quarry, immediately south of the Borstal! Until quite recently quarrymen were working the Freestone of the Portland Beds, but they have now reached a point where the Freestone has become cherty and is no longer useful as a building stone. This change coincides with an algal patch reef, suggesting a shallowing of the sea. The Cherty Beds in the quarry are now being worked for roadstone. We went to the floor of the quarry to see the Basal Shell Bed, but unfortunately it is now covered by talus. John was, however, able to show us loose pieces, and there were many large ammonites in the lime mud below the lowest band of black chert. The varied lithologies of oolites, lime mud and spicule-rich micrites, with whole shells replaced by calcite or dissolved away, showed us how swiftly the environment of deposition must have been changing. We particularly liked the Roach, which rings like a bell, being very hard but full of holes.

Jo Thomas

Severnside at Swansea

On July 26th the newly amalgamated Severnside branch met for the first time near Swansea under the leadership of Dr. Dix, a local OU tutor.

Clement's Quarry at Mumbles was the first stop. Here the Black Lias, so called because the Carboniferous D_3 Upper Limestone Shales resemble the Jurassic Lias, outcrop. The alternating shales and calcite mudstones dip east and north-east off the nose of an anticline. Fossils are abundant in the shales and whilst hunting for these the controversial theories of the mode of origin of the frequent alternations of limestone and shale were discussed.

Then, with difficulty owing to parking problems caused by the glorious sunshine, the cars were parked near Mumbles Yacht Club and the group endeavoured to walk to Mumbles Head along the road without getting run over. (*Sucessfully! - Ed.*)

Just beyond the Yacht Club the D_2 limestone was seen to be lighter than the Clements Quarry limestone and to dip steeply to form the northern limb of the Langland Anticline. Many faults and calcite veins were present, mostly extremely brecciated. Due to downward percolation from a Triassic cover, some of the limestone contained sufficient haemitite to have been mined in the past. Nearer Mumbles Head the D_1 limestone was seen to be an even lighter and to be dolomitised. It was pseudo-brecciated and contained numerous corals and crinoids. Advantage was taken of the glorious day to sit on the Head in the sun and look out over Swansea Bay, correlating the local scenery with the underlying strata.

Next Bracelet Bay was visited, the cause of the bay being apparent from the semicircle of limestone beds - this was the plunging nose of the Langland Anticline. In the centre of this anticline were oolitic limestone $S_b$eds, the oldest limestone to be examined on this trip. At the centre of the bay was a fossil coral reef which contained a large circular coral called *Chaeletes* and fossil algae.

After lunch at a local seashore hostelry the Bishopston Stream section of the Namurian Shales was searched for marine bands containing goniatites, then the stream was followed to the shale/limestone junction, where it disappeared through sink holes.

Finally we returned to Swansea and the Killay Brickworks, where a local cyclotherm is exposed. The coal (Farm Vein) has been mined and only the fireclay is left. This still contains long fossilised roots which can be clearly seen. In the black shales above the coal specimens of *Carbonicola* were found, these shales also being rich in nodules and containing seams of clay ironstone. The succeeding sandstone formed a prominent cliff and could be seen to be ripple-marked.

An excellent day with superb Severnside weather. Lots more interesting trips are planned, so why not join us?

Ann Davies

... and in the Wye Valley

The second Severnside trip was to the Wye Valley on September 6th. Starting at the famous vantage point of Wintour's Leap the morning was spent looking at the evidence for the Tiddenham Chase Syncline. Wintour's Leap is the top of a 400ft lens of Drybrook Limestone within the Drybrook Sandstone. Dave Green, our tutor for the day, proved that the limestone was a S (Seminula) band by finding a *Composita* (formerly called a *Seminula*) in the nearest exposure. Unique to this area, the Dyrbrook Limestone slopes eastwards with a dip of 5-10 degrees, as could be clearly seen from the opposite side of the road, where the synclinal nature of the topography was noted. The eastern limb of the syncline, seen in a quarry 2 miles east of here, has a dip of 65 degrees, so this syncline, like the neighbouring Forest of Dean syncline, is asymmetrical.

Moving onto the Lancaut peninsula, a few hundred yards away, we saw the Lower Drybrook Sandstone below the limestone, but at this point it was some 100ft higher than the base of the limestone at Wintour's Leap. Looking across the river to Piercefield Park we saw the Lower Whitehead Limestone forming the cliffs above the river, and in the river bank saw the lowest member exposed here, the Crease Limestone. The St Aravan's fault and a smaller fault controlled the line taken by the Wye as it cut through this part of the plateau that made up this area until the last Ice Age.

From Lancaut we moved on to The Park, a Forestry Commission site in the Tiddenham Chase, from where we followed the path down to the Devil's Pulpit overlooking Tintern Abbey on the Wye. The first rock exposed along this track is the Lower Drybrook Limestone, which is seen in a small culvert at the start of the track. A hundred yards later, by an Ordanance Survey marker, the rocks could be seen to have changed to limestones, indicating the start of the Whitehead Limestone. A disused quarry beside the track yielded haematised dolomite which probably represented the outcrop of the Crease Limestone in this area. The Devil's Pulpit itself was seen to be a cross-bedded, dolomitised, oolitic limestone, with the cross-bedding being very evident at the top of the pulpit. Dave Green told us that this indicates that the dolomitisation was penicontemporaneous. The Wye here was cut into the lowest member of the Carboniferous, following the line of the soft Lower Limestone Shales parallel to the outcrop of the Lower Dolomite.

The afternoon was spent exploring Old Ham Iron Mine in the Crease Limestone, thanks to the services of OUGS member Clive Roberts and his colleagues in the Gloucester Speiliological Society. This old iron mine is in a heavily haematised area that includes a number of mines. Descending to Railway Churn we saw the 'brush' haematite that was the main reason for the mine and the ochre that often allowed the mine to continue when iron prices were too low to justify the mining of the very low grade ore found here. The ore never got above 12% haematite, and so was very much a marginal deposit.

Martin Bryan